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THE CENTENNIAL EXPOSITION.—THE CENTRE OF THE MAIN BUILDING.

OUR engraving gives a bird's-eye view of the central portion of the Main Building, from one of the galleries overlooking the music stand. An excellent idea of the magnitude, proportions, and general appearance of the colossal structure may from this sketch be formed. Much of the finest art workmanship of this country and Europe was clustered round this centre. To the left of the centre were the spaces devoted to the British Colonies, including the exhibits from India, Canada, Australia, and the West Indies.

THE INTERNATIONAL EXHIBITION OF 1876.—GENERAL VIEW, INTERIOR OF THE MAIN BUILDING.

THE INTERNATIONAL EXHIBITION OF 1876. No. 31.

THE STOW FLEXIBLE SHAFT.

At Section D 68, Machinery Hall, has been on exhibition one of those simple contrivances constituting a considerable improvement in the arts, such as is often met with, only to give rise to the thought or query in a thoughtful or inventive mind: Why has no one thought of or applied this principle before? The thing appears so perfectly obvious, as a device to which a mechanic would naturally resort to effect the purpose which it subserves, that one seems almost justified in entertaining a species of anger at the stupidity of mechanical man for his not having brought this principle into universal use centuries ago. It would not be saying too much to pronounce this device one of the best of utilitarian inventions which has been produced for many years. There is no end to the number of operations in which it may be advantageously used, while it is simple, cheap, and durable.

The merest novice in practical mechanics will comprehend at a thought, that to be able to transmit power in any desired direction, or to any moderate distance desired, or to be able to change the direction at will, is a great convenience; and there are few objects in mechanics upon which more effort and money has been expended than in bevel-gear wheels, universal joints, and other well-known devices for effecting a change in the direction through which motion or power is transmitted; and very few of these have possessed the quality of mobility such as attaches to the instrument which forms the subject of this letter.

It is simply a flexible shaft, which is at once capable of transmitting power to any desired extent, from a motor to an object to be moved, and in any direction at will, either while in motion or at rest. Possessing such qualities, it is applicable to a very great range of purposes, among which may be mentioned: drilling, cutting, and otherwise manipulating heavy metal or other structures such as cannot be themselves conveniently moved from place to place, so as to be brought under the action of stationary power apparatus; drilling large castings, planing small members upon them by furnishing power to the small portable planers, such as have heretofore been used by hand; drilling and cutting in inaccessible places, such as are ordinarily accomplished only with the ratchet-drill, or sometimes with nothing better than a wrench; boring and cutting wood under similar conditions; carving, smoothing, and polishing metals, wood, or stone; clipping horses; sheep-shearing; cloth-cutting, and a thousand and one other operations such as every day invite the use of such an instrument. One of the most advantageous uses to which it has been put is that of actuating the little rotary excavators used by dentists in preparing the cavities of decayed teeth for the reception of the gold or other filling. It has been in use for this purpose for several years, until now no well-appointed dental office is without the elegant little foot-power machine containing this flexible shaft, by means of which the operator is enabled to perform the delicate manipulations required in the preparation of tooth cavities in a far more expeditious and thorough manner than was possible when he was obliged to twirl the minute tools with his fingers while he directed them to the desired spot.

Its use had been confined to this purpose for several years, and even the inventor himself seems to have failed to recognize the feasibility of extending this principle to the transmission of larger powers until at a comparatively recent date. In the space where it was exhibited it was shown in operation in various ways, as in boring wood, facing and polishing marble, granite, etc., and in drilling iron; and to illustrate the facility with which an instrument driven by it may be carried to a distance as well as through a tortuous course, an experiment was made, early in the Centennial days, of drilling a number of holes in a car-wheel in the space of an adjoining exhibitor, which was done to enable the latter to break a piece out of the wheel to show the character of the fracture and extent of chill in the tread. In order to reach this wheel the power was transmitted through three right angles and to a distance of about forty feet.

Wherever the distance to which the power is required to be transmitted is considerable, it is best done, as it was in this case, by relays of the instrument, and although the torsional elasticity of the shaft is small, it is, of course, sufficient to preclude its use for heavy work when the distance is very great.

Fig. 5 shows the general form of it when used for drilling metals, and this form is made large enough to be fully capable of driving a 1-inch twist drill. On the left is seen a round driving belt coming from the line shaft or other source of power, giving motion to a grooved or sheave pulley, which is secured to one end of the flexible shaft. This end is shown as held to the floor or bench by a rope, and is therefore capable of considerable mobility independently of the flexibility of the shaft. To the other end of the shaft is secured a cast-iron yoke carrying a pair of bevel wheels, which drive the vertical drill spindle; and the usual feeding screw above, with the customary drill post, constitutes a most effective, and labor and time-saving, substitute for the ratchet drill. This is only one form of it, and of course it can be varied as to the character of the attachments at either end to suit the kinds of work expected of it. Messrs. Stow & Burnham, the proprietors, make a specialty of furnishing the various forms of attachments, as well as the shaft itself. Besides the uses already enumerated to which this machine may be put, suitable arrangements of it are made for revolving emery wheels, steel brushes, etc., such as are used in cleaning and dressing castings, and for various purposes; for boiler works, in drilling holes which can not be located until the boiler is placed, tapping stay-bolt holes, drilling out broken stay-bolts, cutting out boiler tubes, etc.; in the ship-yard for boring the innumerable auger holes generally done in so laborious a manner by hand, and many other similar purposes.

Fig. 1 shows the shaft with the plain auger attachment; Fig. 2 illustrates the manner in which the shaft and tube are made; Fig. 3 gives in section the construction of the tool end of the shaft; and Fig. 4 exhibits the construction of the pulley end, also in section. These figures generally explain themselves; the construction of the shaft and tube, however, may be described as follows:

The shaft is built up of several layers of wire, the number of layers depending upon the size and strength of shaft required, wound one upon the other helically. The layers are put on in groups of three to eight wires, parallel to each other, each successive layer containing groups of varying numbers of wires, thus giving a different pitch to the helices for each layer, the direction of each twist or helix being the reverse of the one upon which it is wound. When the shaft is laid up in this manner, the wires at each end for a short distance are brazed solidly together, and to these solidified ends the pieces are secured for the attachment of the pulley and tool which it is to drive.

FIG. 5.

THE INTERNATIONAL EXHIBITION OF 1876.—THE STOW FLEXIBLE SHAFT.

This construction, it will be readily seen, produces a shaft which will have considerable transverse elasticity, while it must necessarily offer great resistance to torsional strain, the reversed helices forming a kind of helical trussing, which effectually braces it against torsion. The case within which it turns is simply an elastic tube of leather or other suitable material, within which is wound a single helix of wire fitting its inside tightly, the inside diameter of the helix being a little greater than the outside diameter of the shaft, and wound in a contrary direction to the outer helices of the shaft. This forms a continuous bearing for the shaft; or at least serves as a bearing at the points of contact between the shaft and case which are brought about in the various bending of the whole when in use.

In order to give to the instrument all the transverse elasticity possible, that end of the shaft carrying the pulley is made with a feather so that it may slide endwise in the pulley, while the latter is secured to the case, the case, however, not rotating with it. It will be readily seen that this is a necessary precaution, inasmuch as in the varying curves given to the instrument in use a difference will occur in the relative lengths of the shaft and tube.

It might be supposed that the friction of the shaft within the tube would be so considerable as to militate against the success of the apparatus; but in practice, and under test for the determination of this, it has been found that the friction generated by running it when bent at a right angle does not exceed that when used in a straight line more than 15 per cent of the latter.

In the running of it in a bent position, not only will there be friction between the shaft and tube, but there must also be some little motion of the layers of wire one upon another in the shaft itself; and to provide against the wear and friction which would otherwise occur in this way, provision is made for not only oiling the bearings at the ends, but also for confining a small quantity of oil within the tube, by which all motion of the wires upon one another, or the shaft upon the interior of the tube, is made easy by its being well lubricated.

This little machine meets with the commendation of all who see it, and its adaptability to purposes in which it must be a large saver of time, labor, and money is so extended and various, that it must be regarded as one of the most meritorious conceptions in the mechanic arts that has made its appearance in late years; indeed, it would be a most valuable machine, and one of the best of tools for the machinist, boiler-maker, and worker in metals generally, if it were confined to the single form and purpose indicated in Fig. 5; but with the almost limitless range of its application it is something more than an ordinary invention.

I am indebted to Mr. J. F. Haskins, late president of the Haskins Steam Engine Company of Fitchburg, Mass., who is now general manager for Messrs. Stow & Burnham, for courteous information and access to the machines on exhibition.

J. T. H.

BOAT EXHIBITS AT THE CENTENNIAL.

In this class of exhibits at the Centennial there was an extensive representation, which included vessels and boats of all kinds. There was a superb collection of models of men-of-war, fishing craft, and small boats in the United States Building. In Machinery Hall, elaborate models of ocean steamers, ironclads, race-boats, ice-boats, canoes, and the admirable exhibit of the Massachusetts Marine, which includes vessels of every conceivable description, from skiffs to fast-sailing clippers. In an out-of-the-way corner of one of the mineral annexes of the Main Building, a curious display of Chinese junks; interspersed through all the foreign departments were models of the vessels peculiar to the different countries. In the Agricultural Building, a collection of fishing boats, a large portion of which is in the Norwegian section.

Our engravings represent a number of the most curious and widely differing vessels, selected from the displays of the different nations. Standing in the middle aisle of the United States Building is the gigantic dug-out—an immense canoe hollowed from the trunks of massive trees—by the Vancouver's Island Indians, and measuring 60 feet in length by 8 feet beam. It is made in four pieces, and was probably intended for warlike purposes. In the engraving, the painted bow is represented, covered with the strange picture-writing peculiar to its savage builders. The designs, notably of the eyes, depicted near the bow, curiously correspond with the similar decorations to be found on Chinese junks. This is a slender link, but is perhaps of some ethnological value in indicating the relationship between the tribes, part of which went to the southward in Asia, and part crossed Behring's Straits, and entered the American Continent. The British Columbian whaling canoe, shown above the dug-out, reminds one somewhat of a Venetian gondola. It is made in few pieces, and has a broad gunwhale ending in a fork at the bow. The same strange Indian designs are painted both inside and outside the vessel.

Not very long ago, the yacht "Amaryllis," built on the catamaran principle, vanquished several of the finest centre-board and keel yachts in this vicinity. This circumstance has directed interest to this peculiar mode of construction; and we represent three of these odd boats, as made in as many widely separated parts of the globe. The simplest is the catamaran of the Philippine Islands, which is merely an ordinary canoe having two bent spars lashed athwart ships and connected by rough cross logs at their extremities. These prevent the boat capsizing, through resisting her tendency, when she heels, to submerge them. The anchor used by the Philippine Islanders is likewise represented. It consists of an iron-tipped hook of wood, and is obviously of little value, since there is no way for it to hold bottom unless the hook end falls underneath.

The second catamaran, that peculiar to Pernambuco, Brazil, is of an entirely different species, and is not a true type of its kind. The name catamaran is, however, applied in the navy to an assemblage of empty casks, lashed together and covered with a staging to form a raft; and in some parts of the world any raft of logs obtains a similar title. The present craft is, however, peculiar, because it has a centre-board, an odd appliance for a raft. The cabin, which is just big enough for the occupant to crawl into head first, is mounted on a slanting platform, and there is a huge steering oar held in a high crotch. The sail is odd shaped, and, being widest at the top, is excellently adapted to capsize any vessel on which it may be placed; hence probably the reason for the centre-board. Catamaran No. 3, from the Sandwich Islands, is an elaborate affair, but genuine in its way, inasmuch as it embodies the principle of "united we stand, divided we fall," as all true catamarans should. The main canoe is so very high and narrow that it would promptly upset, even without the aid of its immense mast and sail; but the broad outrigger and solid boat-shaped block at the end thereof hold up the whole fabric. These vessels sail faster than any known sailing craft, and are stanch in the roughest seas. The Hawaiian catamaran is a double-ender—that is, it sails either bow or stern first. It never tacks to turn around. When the ingenious captain desires to go about, he casts loose the forward lower corner of

his sail, hauls it around to the other end of the boat, and makes it fast there. Notice, also, that the mast is stepped on the gunwale and thus brought nearer to the centre of gravity of the whole combination.

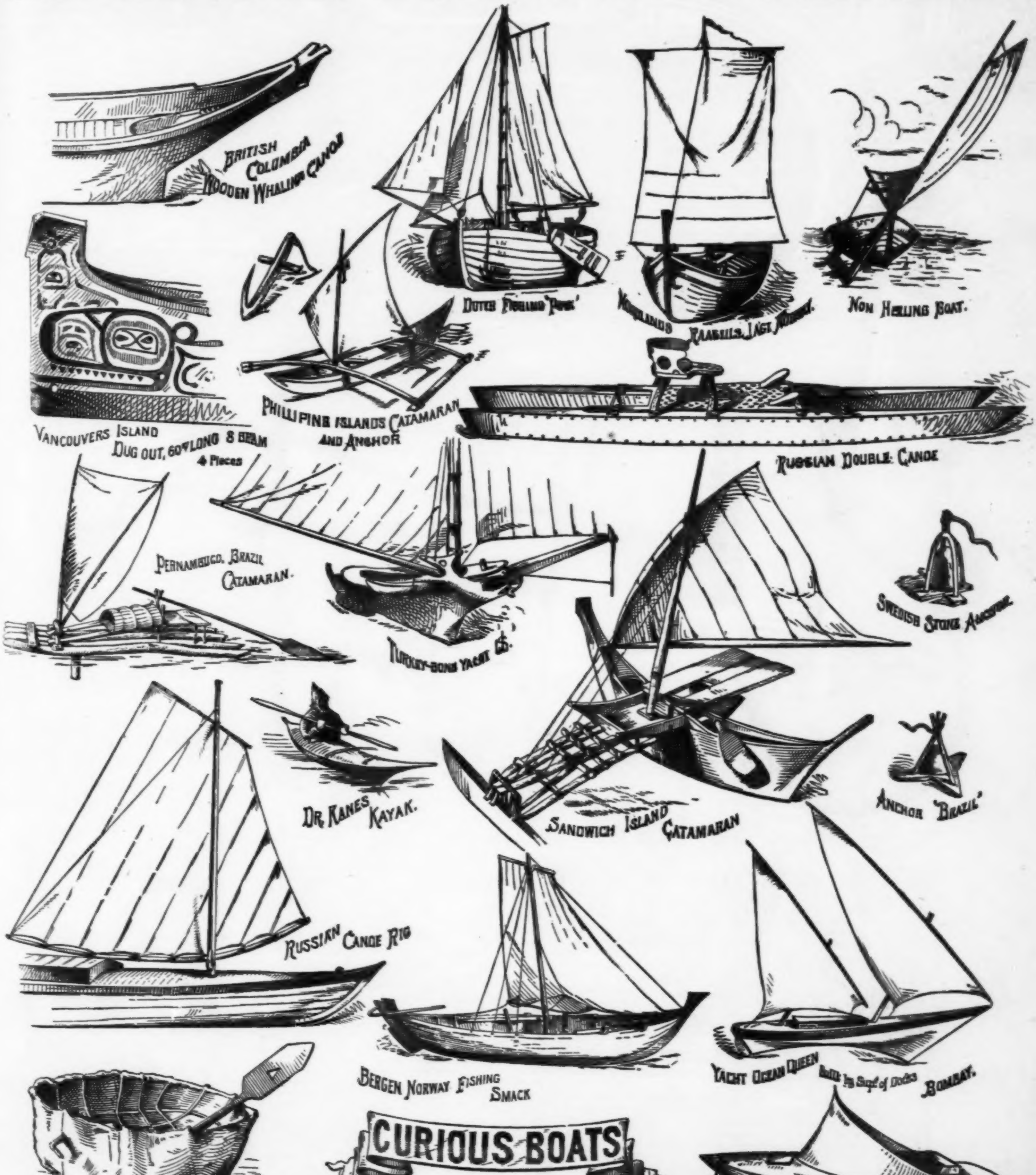
Another curiously primitive boat is the tub-like affair made by the Gros Ventre Indians, of Dakota Territory. It is a mere basket of ash or hickory withs, covered with raw hide, and propelled by the paddle shown. An odd fact here to be noted is, that this craft is almost identically the same as the coracle used on the rivers in Wales for fishing purposes. In fact, no one can study all these kinds of boats without becoming impressed with the similarity of working in the minds of people, utterly dissimilar in race and in every other respect, in order to reach a given object. Compare the old Swedish anchor, illustrated side by side with the like device peculiar to the Brazilian aborigines. The same apparatus is employed by our own east-coast fishermen. Doubtless hundreds of persons have each deemed themselves the original and only inventor of that contrivance.

There are strange contrasts among the boats. The Philippine catamaran is so long and narrow and high that it must, to sail at all, be held up; on the other hand the Dutch fishing pink is so short and broad and low, that it would be difficult to upset it. The craft is very nearly as broad as it is long; the mast is stepped very nearly in the middle of the boat, and there are two bowsprits, although why the ordinary rule of attaching jib and staysail to one spar, is not followed is a mystery. The pink is built for sailing in very shallow water, such as is found on the shoals in the North Sea; and to prevent her drifting to leeward, crab-fashion, huge weather-boards are attached to her sides and dropped vertically into the water to offer a wide area of resistance. These vessels, like every thing Dutch, are usually models of neatness, and abound in varnished wood and brilliant brass ornaments, to the exclusion of paint.

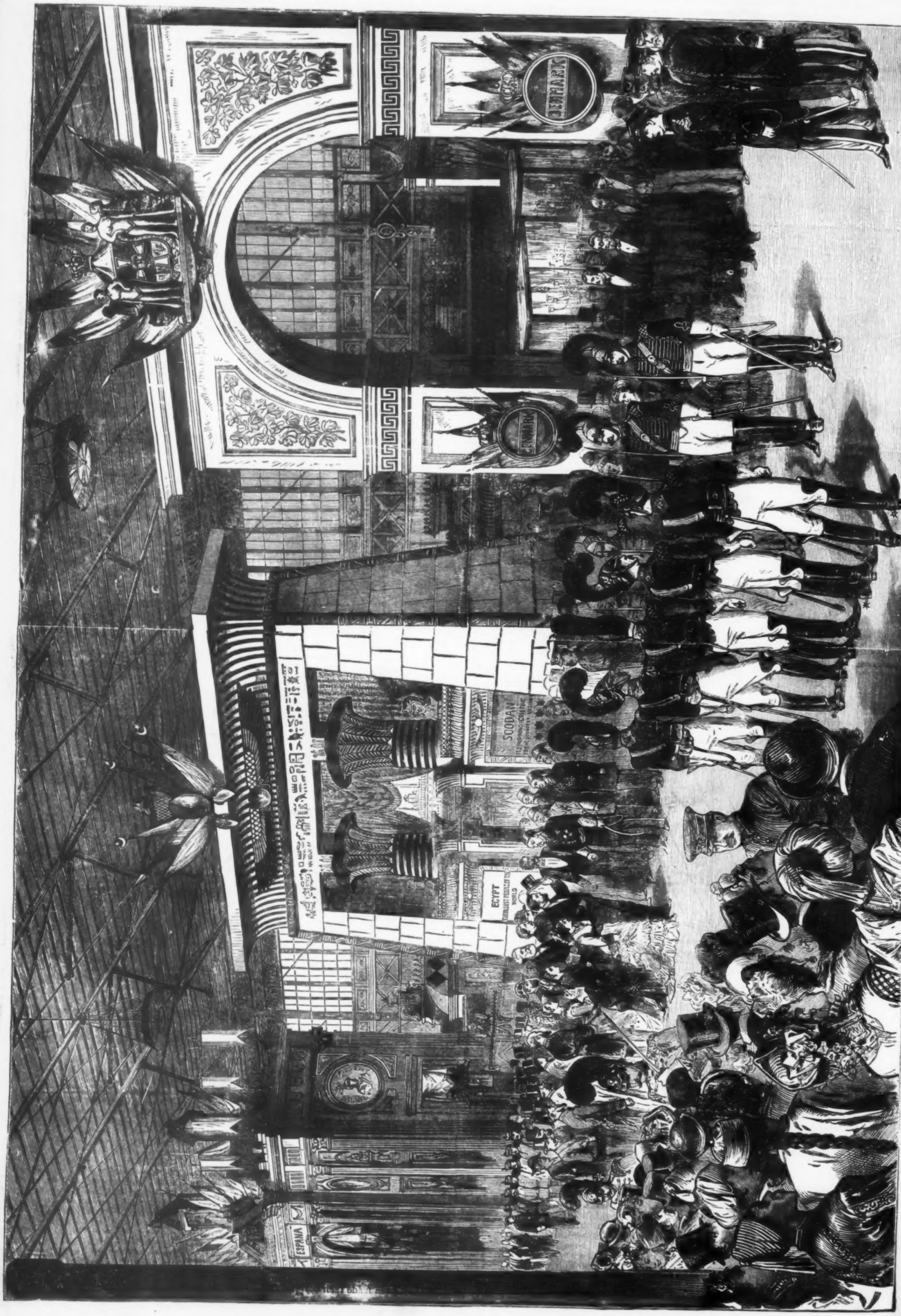
Another sharp contrast is found between the Indian skin boat, already described, and the Greenland kayak or "man's canoe." This boat is usually about 16 feet long, 2 feet broad, and 1 foot deep. The bottom is rounded and has no keel. The frame is kept stretched above by a large number of little beams, and two strong battens run from stem to stern, which, toward the middle, are attached to a hoop of bone large enough to admit the body. The frame is entirely covered, with the exception of the circular hole in the centre, with freshly dressed seal-skin. When complete, the boat weighs about 60 lbs., and is so constructed that it can be carried on the head without the aid of the hands.

The vessels in which the ancient Northmen made their voyages, which resulted in the discovery of America and Iceland, or in which the Danish Vikings sailed on their pillaging expeditions to the coast of England, find their modern reproductions in the Norwegian craft now used for fishing and pleasure purposes. The high prow, whereon was the dragon's head in ancient times, may be traced in both the Nordland's raaseils (reefed sail) yacht and the fishing smack which we illustrate. The former has the old square sail, and in model is almost the same as the Vikings' vessels.

The curious Russian double canoe was in the Russian section of Machinery Hall. It is a beautifully made craft, having a hull in two portions, and a comfortable arm-chair located on a grating between. The Russian single canoe has a neat rig, easily managed by the sole occupant of the vessel. The gaff is fitted with halliards and downhaul, leading through fair leaders to the cockpit. Another type of vessel, which disputes with the canoe the supremacy for pleasure purposes, is the duck boat. Our sketch is taken from the craft in which Mr. N. H. Bishop, of New York, made his famous voyage from Pittsburg *via* the Ohio and Mississippi rivers to the Gulf of Mexico, and thence to Cedar Keys, Florida, a distance of 2600 miles. The boat is very wide, and draws but very little water. The screen shown serves as a protection against the weather, and as a tent at night.



CURIOUS BOATS AT THE CENTENNIAL EXHIBITION 1876.



THE INTERNATIONAL EXHIBITION OF 1876.—VIEW IN THE MAIN BUILDING.—THE GATEWAYS OF THE NATIONS.

The celebrated yacht "America," a vessel which won her laurels in 1851, and which our yacht builders, with all their skill, have never yet improved upon, had masts which raked heavily aft, and she drew nearly three times as much water aft as forward. Despite the speed and other advantages thus gained, a shipbuilder in Bombay has constructed the "Ocean Queen" in diametrically the opposite way, and claims that she beats steamers, making, with a favorable breeze, some 20 knots per hour. The masts rake, Malay style, greatly forward, where the heaviest draught of water is found. It remains for naval architects to reconcile the discrepancy if they can.

The last two vessels which we have to describe are essentially the outcome of Yankee ingenuity. The first is a nonheeling boat. The hull is hung on pivots in a heavy frame, which constitutes stern-post, stem-post, and keel in one. The mast is stepped in the stern. Consequently, when the wind pushes the sail horizontally, the keel, etc., are alone lifted, while the boat remains perpendicular. The turkey-bone yacht, some ingenious New Englander has contrived from the sternum of the turkey. It is needless to say that its size is diminutive, and that it is not intended to sail. A deck is attached to the under part of the bone, the narrow projecting part of which forms the keel. Rudder, bowsprit, mast and sails, and small boats complete the resemblance to a miniature sloop.

GATEWAYS OF THE NATIONS.

WE give on the opposite page a fine engraving of a portion of the interior of the Main Building at the Centennial. The artist has represented the procession which, headed by President Grant and the Emperor of Brazil, passed through the different edifices immediately after the opening ceremonies. The distinguished party was received by the various foreign commissioners, who, with their respective committees, had posted themselves in front of their departments and along the principal aisle. The three gateways, shown in the illustration, belong to Spain, Egypt, and Denmark, and were the most elaborate temporary decorations erected within the edifice. Egypt surrounded her entire section with a low wall of wood and canvas, painted to imitate stone. There was a noticeable absence of display of this kind in the departments of England and France. England, especially, avoided even ornamented show-cases, and presented her exhibits in plain but handsomely made cases.

THE GREAT CATARACT OF THE CENTENNIAL.

THERE were few more attractive features in the Exposition than the wing or annexe of the Machinery Hall which was devoted to the display of the hydraulic apparatus. Long before the locality was reached the sound of "the rushing of mighty waters" reached the ear, drowning the clatter of the vast area of mechanism in the vicinity; and the eye was greeted by a score of great streams, first curving majestically into the air, then lashing the waters of the huge tank below into spray; while in rear of all, a moving background of crystal and foam, falls the grand cataract. From a point behind this superb sheet of water, our artist prepared the drawing from which the annexed engraving was made. The tank, an immense brick and cement basin 146 feet long and 60 feet wide, the bottom being 8 feet below the floor of the Hall, with the water-level 14 inches below the floor, contained nearly 500,000 gallons of water, used over and over again in the pumps, and drawn off only when it became foul and unfit for use, when a new supply was let in from the mains.

THE INTERNATIONAL EXHIBITION OF 1876.—THE GREAT CATARACT.

At the south end of the basin was the apparatus for testing turbine wheels, and this includes the miniature Niagara already referred to. Upon six columns, three of which are supported upon an oblong pier, erected within and near the end of the reservoir, and extending across it to within about 4 feet from each side (the other three resting on foundations within the basin) is placed a tank of boiler iron 36 feet long by 18 feet 6 inches wide and 5 feet 6 inches deep. On the side of the tank, overhanging the reservoir, is a weir overflow of the proper curved form, extending the whole length, and placed about 32 feet above the level of the main tank; by means of which weir, measurements of water discharged may be made. It holds about 10,000 gallons. The water falls over the weir into the tank in a single magnificent sheet, at the rate of 30,000 gallons per minute. This supply is maintained by two Andrews' centrifugal pumps of 100 horse-power each, which are able to fill the tank every 38 seconds and to empty the main reservoir in 16⅔ minutes. The elevated tank also serves to obtain a head under which other pumps may discharge while under test. From the bottom of it is led, directly downward, a penstock tube 4 feet in diameter, and immediately under it is a cylindrical chamber of brick and cement 8 feet in diameter, built in the foundations of the tank columns. In this chamber exhibits of working water-wheels were placed.

Ranged along the sides of the main reservoir were numerous hand and steam pumps of all sizes, grades, and patterns, the steam apparatus having delivery pipes measuring from 1 inch to 12 inches in diameter. These pipes are represented in the engraving at about 12 feet from the floor, and projecting over into the tank.

PORTUGUESE SALT EXHIBITS AT THE CENTENNIAL.

IN the Portuguese section, in the Main Building at the Centennial Exhibition, was exhibited a collection of fine specimens of salt obtained from the sea water at the works at Aveiro, Portugal. As the salt is beautiful in color, of an excellent quality, is produced by an economical method, and is sold at a low price, a short description of the works and process may not be uninteresting or uninstructive.

On the western boundary of the district of Aveiro, on the sea-coast of Portugal, is situated a large plain, little above the level of the sea, and from north to south about thirty-six miles in width. In the centre of this, and more conspicuously outlined, is a natural basin, overflowed by the sea, and known as the Ria or estuary of Aveiro. This basin affords three valuable products, which bring in over $200,000 per year, namely: fish; *molico*, a species of seaweed used as a manure; and salt. The obtaining of this last from the waters of the sea is one of the chief industries of the town of Aveiro.

These *marinhas* (salines) are spaces of ground, enclosed by walls of sod—a sort of argillaceous marl is used, obtained from the basin—and divided into various sized compartments, of graded depths, where the salt water is introduced, and allowed to stand or is stirred, according to the exigencies of the process. These salines are necessarily constructed, so as to lie above the level of low-water, and below that of high, and to have good communication with the canals of the estuary.

The best way to describe the works will be to follow the salt water in its journey through one of them, during which it is evaporated by the sun and wind, the latter being a powerful agent.

The salt water runs directly from the estuary, by means of an underground pipe, into a large basin, known as the pond, whose width is that of the saline, and which is the largest basin in the system. The water then passes through two openings, cut across a thick wall, known as the pond's traverse, into two basins similar to the pond, but each less than one quarter its size, and having a smaller depth, which together stretch across the saline from wall to wall, having a low divisional between the two parts; these two basins are collectively known by the name of the pocket. From these two basins the waters little by little daily spread all over a system of reservoir basins, gradually decreasing in depth, and known under the generic name of the *mandamentos*. There are four rows of basins in this system, eleven basins in each row, the basins gradually decreasing in length to the last row. These basins are divided from each other by small low walls, known as traverses, where the portals are opened. The openings through which the water passes in its journey through this system of basins are known as the portals, and there are as many portals as there are basins. The first row of basins are known as the trenches, the second as the upper pillows, the third as the cuts, and the fourth as the pillows. For its passage through this system, the portals are daily opened, and then stopped up after the required quantity of water has passed through. The *mandamentos* section is separated from the next group of basins, known as the new and old salines, by dividing walls and a ditch, known as the main race, which belongs to both the new and old salines. The water passes from the *mandamentos* into this main race, from which it is distributed among the different *meios*, of which the new and old salines are composed; these *meios* are the last places the water reaches, and where crystallization takes place. The system of basins known as the new and old salines is divided into four rows of thirty-three basins each. The first row are known as the upper middles of the new or upper saline, divided from each other by races, through which the water finds its way from the pillows to the old saline. Next comes a narrow platform, known as the interior teaboard of the new saline, which divides the upper middles from the next set, known as the lower middles of the new saline. Next comes a wider platform, known as the main teaboard of the new saline. These teaboards are platforms on to which the salt is dragged from those *meios* known as lower middle basins of both new and old salines, or crystallizing basins. A small race runs along next to the upper teaboard of the new saline. Through this the water passes, discharging into the *meios*, through little gaps, which, by their communication with the small races, above mentioned, as dividing the *meios* of the new saline, supply the *meios* of the old saline with the requisite amount of salt water. Next come the set of thirty-three basins known as the upper middles of the old or lower saline; these are divided from each other by low walls and small channels, and bounded by the interior teaboard of the old saline. Across this the water runs to the lower middles of the old saline, upon which the crystallization takes place, as it also does upon the lowest middles of the new saline. The platform next is the main teaboard of the old saline. The *meios* in the whole system are divided by additional low walls into quarters, as they are called, of six *meios* each and one of three *meios*. Next to this last teaboard runs the *intervallo*, a ditch about 6½ ft. in width, where the mud removed from the *meios* is thrown.

The entire system is now ended by the *mahadal*, a portion of the outer or protecting wall which surrounds the entire saline. This is widened in two places into large platforms, known as the *eiras*—literally, a barn or threshing-floor. These are connected directly with the upper teaboards of the old saline. On to these the salt is carried from the teaboards, heaped up, and kept until shipped. Under the *mahadal* runs the *bomba* or draining pipe.

The capacity of a saline and its value is known by the number of *meios* it contains, they being nearly equal in dimensions. Hence a saline is said to have 20, 30, or 40 *meios*.

The following are the dimensions of a saline similar to the one which has been described, and containing 33 double *meios*.

The entire saline measures 68.020 square metres. The pond, 22.139 square metres. The pocket, 9.072 square metres. The entire trenches, 5.804 square metres. Each trench, 14.4 square metres. The entire upper pillows, 4.746 square metres. Each upper pillow, 12 square metres. The entire cuts, 4.192 square metres. Each cut, 10.4 square metres. The entire pillows, 3.547 square metres. Each pillow, 8.8 square metres. All the upper and lower *meios*, 9.636 square metres. Each *meio*, 73 square metres. The teaboards, 668 square metres. The ditch (*intervallo*), 334 square metres. The *mahadal*, 307.4 square metres. Each *eira* or salt platform, 135 square metres. The outside walls, dividing walls, etc., 7.414 square metres.

In the pond the water is 0.50 metres deep; in the pocket, 0.18 metres; in the *mandamentos*, 0.054 metres; and in the upper and lower meios, 0.014 metres.

The exterior wall or boundary of the saline, which is a sort of dyke and protects it from the encroachments of the sea, is raised high enough above the spring tides to make it safe. Repairs are needed every year on this outer wall, as also on the inner ones, to make up for the ravages of weather and sea. The bottoms of the different compartments have also to be kept water-tight, and all the different ways have to be kept well cleared up. In March or the beginning of April of each year this work of general cleaning up and repairing is commenced, the walls repaired, the water-ways cleared, and all the compartments thoroughly cleaned. The operations of this general cleaning up are very carefully carried out, and last until the end of June.

After this preparation is finished and the water has found its usual level in the saline, the workmen begin to break up the crystallized salt in the *meios*; this operation is performed every two or three days, and the salt is dragged to the tea-

boards by wooden scrapers. On the teaboards it is heaped in small piles, and when all the *meios* have been scraped, the salt is carried to the *eiras* (salt platforms) in large baskets, where it is heaped in conical piles or in the shape of triangular prisms, having at each end half cones; these are known as mules.

Each day water is let into the lower *meios* through the interior or middle teaboard, passing in from the upper ones, to which water is also admitted each day from the pillows. The water in the cuts, upper pillows, and kettles is each day changed, and passed on so long as the salines are crystallizing.

In the pond the water is admitted and let out every fortnight, in full and new moon during the spring tides.

If the salt should not be sold during the salt-making season, the piles on the salt platforms are trimmed up and beaten with a tool for the purpose, and covered with bulrushes to protect it from the winter rains.

The great enemy of the salt-making industry is rain, which interrupts the process, and often even stops it entirely for the season, soaking the saline and overflowing it.

The Portuguese method of salt-making differs but little from that used on the west coast of France.

The salt of the salines is white, and has a density of 2.125, as before mentioned. The great agents for the evaporation of the salt in these salines are the sun and the wind, the latter being a powerful agent. During north-east winds the salt must be scraped and dragged off every day, as the crystallization takes place very rapidly.

The expense of labor in these salines is slight, one of 33 *meios*, an average dimension, requiring only two workmen; namely, the salt-maker, and an assistant. This force is increased by one or two workwomen to carry the salt from the teaboards to the *eiras*, when crystallization is rapid.

The owner of the salines divides his profits equally with the salt-maker, and the workman is paid about twenty dollars for the season from April to September. The workwomen are paid ten cents per day. The seaweed grown on the bottom of the pond is sold, and the profits shared between owner and maker. When the outer walls are wide enough, as is generally the case, they are tilled, bearing good crops of potatoes, Indian corn, barley, rye, and wheat. This is the perquisite of the salt-maker.

The average production of a 30 *meios* saline during the crystallizing season is 9360 *alquieres*, or about 14,658 pecks of salt. When there is much rain this production is much lower, but with warm and windy weather the amount of salt produced may be three times that above estimated.

The total number of salines in the estuary at Aveiro is four hundred and fifty. The average yearly production of salt can be estimated at 1,624,000 bushels.

Oporto uses a good deal of this salt, and it is supplied to other parts of Portugal, while there is a small exportation to other countries.

Though the price of the salt varies, ten cents per hectolitre (=2.8 bushels) is a fair price, and the annual production averages about $58,000. The production of salt in the district is each year increasing. A saline costs to build from $300 to $400, and is worth, according to the number of *meios*, and its situation on the plain, from $1000 to $1500.

The manuscript from which the above was collated is dated Aveiro, 14th January, 1876, and is signed by Silverio Augusto Pereira da Silva, engineer, and by Franciso Antonio Marquis of Moura, and was evidently written by the former. It is accompanied by a large drawing of a saline and of the instruments used. For facilities in connection with this article the writer is indebted to Senhor Lourenço Malheiro, engineer of mines, Portuguese Commissioner to the Centennial for the Industrial Department.

THE END OF THE YEAR.

THE present, No. 52, is the last number of the SCIENTIFIC AMERICAN SUPPLEMENT for the year 1876.

Our regular dating day is Saturday; this year there happen to be fifty-three Saturdays. To make our datings correspond with the fifty-two weeks of the year, we place on the present issue the double dates of Saturday, December 23, and Saturday, December 30.

Our next number will be the first of the new year, and will bear date, Saturday, January 6, 1877.

THE INTERNATIONAL EXHIBITION OF 1876.

No. 32.

SOME OF THE RESULTS.

Now that the great Exhibition is at end, and "chaos has come again," it may be profitable to glance over some of the principal facts and figures which have grown out of it, and to compare the results so far as they may at this early day be comparable, with those of the world's fairs which have gone before; and it will be appropriate to thus look over the work in this last number of the SUPPLEMENT for the Centennial year which gave it birth.

To attempt now to picture wholly the probable results of this Exhibition and its effect upon the industries of this country, would require more than human prescience; but we may be sure that such will be the deep and lasting impulse given by it to the arts and sciences, as well as to our commercial and industrial interests, that it will not be too much to say that its influence will be felt for generations to come. We may now, however, from some of the most prominent facts and figures, glean something of an idea of the value it will prove to have been to every material interest of ours and of the world.

Aside from the national and patriotic features attached to its origin, which, no doubt, lent much to its substantial and financial success, and considered rigidly as an International Exposition of the world's industries, it will be admitted on all hands that it has in every possible aspect been more than successful, while in magnitude, diversity, arrangement, and pecuniary results it eclipses all similar efforts which have passed into history. The material resources of our vast domain; the inventive genius of our mechanics and manufacturers; the rapid development of this young people in music and the fine arts; the extraordinary aptitude in the discovery and application of labor-saving appliances; the wealth of systematic provision for purposes of education; the wonderful elaboration of that most powerful of modern institutions, the newspaper press; and, in a word, the magnificent progress made in all that contributes to the happiness and prosperity of man by a country and people not a century old, will be so thoroughly impressed upon the older countries by their several representatives, that the advantages to us as a people, to come from this Exhibition, will be felt for many years. Many of the commissioners from abroad have availed themselves of their six months' sojourn with us to make extended tours through the country, and have in this way had the favorable impressions created by the Exhibition supplemented and enforced by a personal acquaintance with our principal industrial centres and establishments, which can have no other result than to impress them in every way favorably to a more extended and profitable intercourse with us in the future; and while our contact with them will have the desirable effect of enlarging our views and making us more liberal and cosmopolitan in spirit, they will be found to be equally benefited, and to carry with them some of the push and snap of the American to infuse into the older and more staid peoples which they came here to represent.

To say, then, that the Exhibition will be much to our manufacturing, mercantile, and commercial advantage, in bringing customers from abroad or making a more extended market for our products, is to say the least; and our country and people will be brought to the knowledge of the others of the world with reference to the extraordinary possibilities of such a nation and land in a light such that when the reports of the several commissioners have become disseminated among their own peoples, the United States of America will be better known and understood by them than could be possible through any other human agency; and these foreign peoples will be the gainers as well as ourselves. But we will also have learned much from the magnificent displays made by the foreign nations and exhibitors; many of our peculiar American idiosyncrasies will be advantageously toned down, and a great deal of that sober, solid method characteristic of the older countries will become infused into our plans and processes; our tastes in all the fine arts will be elevated; we will acquire a greater relish for the beautiful, the quaint, and the old in such things, and attach a value to æsthetic studies and objects far above what has been true of us in the past; and in this way the International Exhibition of 1876 will exert greater influence than any of its predecessors in all that redounds to true progress in this country and in the world.

To us Americans, however, the Exhibition has a significance which could not obtain with any of the other peoples at previous world's fairs. This has been so intimately associated with our highest instincts of nationality and patriotism, that in years to come it will live in the minds of our people as an event second only to that Declaration of Independence which it was its primary object to commemorate. Of the millions of pilgrims to this American Mecca there is probably not one who has not taken with him or her one or more mementos or *souvenirs*, to be installed among their household gods, and in the course of years to be transmitted into priceless heirlooms; and, after the expiration of perhaps four or five decades, every household in the land will contain some little article, treasured up and handed down from father to son, as a witness of the visit to or some connection with the great Centennial Exhibition on the part of some member of the family, whose departure from earth will have made for these articles a holy and inestimable value. In this light the Centennial has yet to do a great work in the land in cementing opposing interests, modifying sectional bitterness, and in bringing about that perfect national brotherhood that has of late years been so seriously disturbed.

Its beneficial effects upon the educational methods and institutions of the country alone will be something that is not to be overestimated; and, as in the education of the coming generations lies the foundation and permanence of our institutions and form of government, it would have been the grandest event in the history of this country since the foundation of the government if its effects were to be felt in no other direction than this.

The primary object of the average exhibitor in such an exhibition is that of a future material gain, a hoped-for increase of business by reason of bringing their wares more prominently before the world; and so far as it goes this is a most praiseworthy motive, and is of lasting benefit to the country at large in proportion as it is successful. But the men and governments who have expended so much money, time, and talent in placing in friendly rivalry the enormous amount of educational material on exhibition must have had a higher and less sordid motive.

The extensive and costly exhibitions made by the several foreign nations and the different State governments from ourselves, to say nothing of the displays of the many individual institutions of learning, could not be expected to return to them any thing but loss in dollars and cents; but the results of this interchange of ideas and methods among men of learning and the teachers of the world will be as valuable to all as may be pictured in the idea that they separate to go to their respective localities, each in possession of the combined experience of the whole.

Few visitors to the Centennial, aside from those who have had educational investigation directly in view, have any conception of the immense amount of this kind of material which was there to be seen, and a mention of some of the more prominent of them will be in place here, and will serve to show how extensive it was as a whole.

The United States alone made 184 distinct exhibits of this kind, prominent among which were: The New York Institution for the Blind, showing the methods of imparting instruction to this unfortunate class of people; an exhibit made by the Superintendent of Public Instruction in Baltimore; the American Missionary Association of New York; the Ingham University, Le Roy, N. Y.; the Massachusetts Institute of Technology, Boston, Mass.; the Stevens Institute of Technology, Hoboken, N. J.—a magnificent exhibit, described and illustrated in a previous letter; the Cornell University of Ithaca, N.Y.; the Cooper Union Evening School of New York; the Hampton Normal and Agricultural Institute, Hampton, Va.; the State of Indiana Educational Department—a very extensive and complete collection relating to the entire system and methods used in the State; the exhibits of the States of Michigan, Wisconsin, Ohio, Nebraska, that of the Rhode Island Board of Education; the New Hampshire Department of Public Instruction; the State of Connecticut Educational Department; the States of Illinois, Maine, Iowa, Missouri, Maryland, and Tennessee; the magnificent and extensive display of the Commonwealth of Massachusetts' Department of Education and Science, occupying the whole of the gallery upon the east end of the Main Building; the State of Minnesota Educational Department; the State of New Jersey's Department of Public Instruction; the State of Pennsylvania Educational Exhibit, made in the separate building known as Pennsylvania Educational Hall—a building 100 by 100 feet, with two wings, each 40 by 24 feet, devoted exclusively to that which relates to methods and results of teaching in the State; the Methodist Book Concern, New York; the Presbyterian Board of Publication, Philadelphia; the National Temperance Society, New York; the American Sunday-School Union of New York; the American Bible Society, New York; the American Tract Society; the Fireland Historical Society, Ohio; the Agricultural College of Ohio; the Archæological Society of Ohio; the Western Reserve College, Hudson, Ohio; Buchtel College, Ohio; Mount Union College, Ohio; the Ashtabula County Historical Society, Ohio; the State Archæological Association of Ohio, and the Western Reserve Historical Society of Cleveland, Ohio.

From foreign countries there were 1041 distinct exhibits of this kind, many of them very extensive and comprehensive; as for instance the exhibit of the Technical School of Moscow, Russia, and the collection of the Educational Department of Toronto, Canada. Of these foreign exhibits, Great Britain sent 41; Victoria and New South Wales, 13; Canada, 48; France, 84; Germany, 160; Austria, 10; Switzerland, 68; Belgium, 38; Netherlands, 23; Sweden, 48; Norway, 6; Italy, 28; Brazil, 39; the Argentine Republic, 18; Portugal, 20; Turkey, 2; and Russia, 33.

To these we may add the separate educational structures known as the American Bible Society Pavilion, the American Kindergarten, Frobel's Kindergarten, and the Swedish Schoolhouse, and we have a wealth of educational matters which is simply astounding. The fact that there was upon the Exhibition Grounds no less than 1225 separate and distinct exhibits of an educational nature, is of itself sufficient to show the superior importance given to all that relates to the mental training of the young in these days; and one needs no better criterion of the grand results which must flow from such an assemblage, and the opportunity for interchange of plans, ideas, and methods which doubtless was made good use of at the Exhibition by all interested in such matters.

When we consider the opportunity offered by such a collection for the improvement of all that relates to the acquisition of knowledge, it can not be doubted that here seed will be sown which, as the world grows older, will germinate and ripen into a harvest which will work greater good to the world and improve its sociological condition beyond any event in the history of mankind.

Next to educational matters, perhaps, the manufacturing interests of our own country will be most affected by it, and of these the iron and steel industry will be most benefited. The extraordinary display of Mining and Metallurgic products in the Main Building, described in two previous letters, can not fail to open up to the eyes of strangers the enormous resources of this country in coal, iron, and other useful and precious metals and minerals. From the different parts of this country there were no less than 551 distinct exhibits which come under the head of Mining and Metallurgy. Under the head of Machinery there were over 1500 exhibits, exclusive of those of leather and leather products in the Shoe and Leather Building, which also came under the supervision of the Machinery Bureau. In this general branch of manufacture (machinery) we have exhibited to the world a collection of the productions of our mechanics and inventors of which we may well be proud, and which will establish a reputation for us abroad which the oldest and most experienced nations may hereafter look for in vain. The Machinery Hall, with the several buildings included in its management, with their contents, have been looked upon by many of our foreign visitors as a marvel in its extent and the wealth of ingenuity and mechanical skill displayed therein; and certainly this bureau is entitled to no small credit for the share which it has contributed to the general success of the Exhibition. So well has this been conducted in a financial point of view, that, notwithstanding that it is necessarily the most expensive of all the departments, the receipts from concessions and percentages upon sales have paid all expenses of the bureau and left about $12,000 of a surplus.

I might go on and particularize as to the other bureaus, and show how successful in every way have been those of Agriculture, Horticulture, Art, and Installation, as well as the Department of Admissions, the Police and Fire Departments, and the minor powers of the Exhibition, and the whole would result in only the same story of economical and successful management; and in days to come, when it is remembered that this grand result has been reached during an unprecedented depression in business interests, which lasted from its inception to its close, too great a meed of praise cannot be bestowed upon the Centennial Commission and Board of Finance, the Director-General, the Chiefs of Bureaus and their assistants, who have all contributed their share to the now well-assured success.

An approximation to a few of the principal figures, which will tend to illustrate the immediate material success of the Exhibition, in such shape as to be easily stowed away in the memory, may not be amiss here. Early in the present year, and perhaps as late as two months previous to the opening day, it was given out, or at least hoped, that the number of buildings would reach the Centennial number of 100, but some weeks before the opening it was found that this number would be exceeded; and long before the closing day, the total number of separate stuctures upon the grounds reached 190, or nearly double the highest at first hoped for. Of some of the larger buildings, the areas presented by them available for exhibition purposes are as follows: Main Building, $21\frac{1}{2}$ acres; Machinery Building, 14 acres; Agricultural Building, 10 acres; Horticultural Building, $1\frac{1}{2}$ acre; Art Building, $1\frac{1}{2}$ acre; Women's Pavilion, $\frac{3}{4}$ acre; Government Building, $2\frac{1}{4}$ acres; Carriage Building (Main Building Annex), 2 acres; Brewers' Building, $\frac{1}{2}$ acre; Shoe and Leather Building, $1\frac{1}{6}$ acre; Dairymen's Building, $\frac{}{8}$ acre; Photographic Hall, $\frac{3}{4}$ acre; Kansas and Colorado Building, $\frac{1}{6}$ acre; Arkansas State Building, $\frac{1}{6}$ acre; Gillender & Sons' Glass Factory, $\frac{1}{5}$ acre; the Campbell Press Building, $\frac{1}{4}$ acre; Spanish Government Building, $\frac{1}{6}$ acre; Singer Sewing Machine Building, $\frac{1}{10}$ acre; Swedish Schoolhouse, $\frac{1}{10}$ acre; Pennsylvania Educational Building, $\frac{1}{6}$ acre; French Engineering Building, $\frac{1}{10}$ acre; Boiler-houses and Annexes to Machinery Hall, 1 acre; Saw-mill Building, $\frac{1}{2}$ acre; Pomological Building, $\frac{2}{3}$ acre; Annex to Horticultural Hall, $\frac{1}{6}$ acre; Art Gallery Annex, 2 acres; and Mineral Annexes to Main Building, $\frac{3}{4}$ acre.

These buildings were all devoted strictly to exhibition purposes, making, with a number of smaller bazaars and other structures containing goods of some kind on exhibition, a total of not less than 65 acres of space used for legitimate exhibition purposes. If we compare this figure with the space similarly occupied at previous exhibitions, it will be seen at a glance how far it has exceeded every thing of the kind. The London Exhibition of 1851 covered 20 acres; the Paris Exhibition of 1855 covered 40 acres; the second London Exhibition of 1862, 24 acres; the Paris Exhibition of 1867 had under cover about 40 acres, and at the last Exhibition at Vienna, in 1873, about 20 acres. Thus the American Exhibition exposed goods upon an area greater than any other two except the two French fairs, and more than one and a half time greater than either of these.

The admissions to the Centennial were as follows:

Total cash admissions..............	8,004,274
" free "	1,906,692
Total admissions..............	9,910,966

The total receipts from admissions were $3,813,724.49. The greatest total number of visitors in any one day was on Sep-

tember 28th—about 275,000—and the receipts for that day $118,673.75. At London in 1851 the total number of admissions were 6,039,195, and the greatest number in one day 109,-915. At Paris in 1855 the total admissions were 5,162,330, and the most in any day 123,017. At London in 1862 the total admissions were 6,225,000. At Paris in 1867, which was open much longer than ours, the total was estimated at nearly 10,000,000, and the largest for one day 128,000; and at Vienna in 1873, neither was so great: so that in the matter of total number of visitors we have outstripped them all, except possibly the Paris Exhibition of 1867 (and for an equal number of days open this was exceeded), and by more than double the largest for any one day, while the receipts are very greatly in excess of any of them.

The total amount of money received from concessions was $290,000, and from percentages on sales of goods $203,000, making the total receipts from all sources $4,296,724.49. What the expenses have been, or more properly will be, can not yet be told, inasmuch as a very considerable part is now being incurred. A considerable revenue is, however, to flow to the Board of Finance from the disposition of buildings and material, and this was commenced on December 1st, by the sale of the following buildings, which were sold at auction, and for sums and purposes as follows:

Main Building, cost $1,600,000, sold for $250,000 to the International Exhibit on Company of Philadelphia, for the purpose of a permanent exhibition, which is already incorporated and well under way. The Mineral Annexes cost over $19,000, sold for $1000; Carriage Building cost $55,000, brought $4100; Photographic Hall cost about $23,000, sold for $1000; the Art Gallery Annex cost $110,000, brought $3050; Judges' Hall cost $30,000, was sold to the Permanent Exhibition Company (to be used for offices) for $1500; the Medical Building sold for $390; the Public Comfort Building, which cost $22,000, went for $1030; the Shoe and Leather Building cost $32,600, sold for $3000; Agricultural Hall, which cost $275,-000, brought $13,100; and twenty-four other smaller structures sold for various sums, bringing the aggregate up to $296,160 for buildings that cost to build not less than $2,500,000. Horticultural and Memorial Halls are not at the disposition of the Board of Finance, but are to remain permanently in commemoration of the Centennial. Machinery Hall is the property of the city of Philadelphia, and recently the City Councils have decided to permit it to remain, and propose placing it in the hands of the Franklin Institute, in which to establish their museum and hold their future exhibitions. The Corliss boiler-house was purchased by a representative of the Institute for their use in connection with Machinery Hall. The last-mentioned building cost $636,500.

The value of exhibits in Machinery Hall and the building and annexes belonging thereto, including the Shoe and Leather Building, was:

Value of goods exhibited	$2,471,178
Cost of cases, etc., and attendance	1,103,897
Total value	$3,575,075

It would be interesting to know the total money value of every thing that was brought upon the ground, including all expenses attendant upon the preparation, inauguration, conduct, and closing out of this great enterprise, and in due time this will be made known, as a complete valuation of every thing upon the grounds has been in progress for a considerable time, but is not yet completed in all the departments.

With the exception of the Main Building, Judges' Hall, and the Corliss Boiler-house, it is not known to what purpose the purchased buildings are to be put; with the above exceptions, however, they are all to be removed from the grounds.

The total number of awards to exhibitors will reach nearly 14,000. A number of them are still under adjudication, and the complete list will not be ready for some little time. As with the other figures, this largely exceeds the number of awards made at any previous Exhibition; whether it will give proportional satisfaction to the recipients is something yet to be decided. There is no more disturbing element or knotty problem in connection with these exhibitions than the distribution of awards to competing exhibitors, and out of the dissatisfaction at the methods previously adopted grew the new experiment which has been tried here. Many, no doubt, now see—or think they do—where it may be improved, and some will regard it as inferior to any of the precedent systems. When, however, the calm second thought of those interested has come, and an opportunity has been had to see the best as well as the worst features of it, I am of the opinion that it will be generally pronounced as by far the best of any of the systems yet adopted.

In the work of preparation and conduct of a work of such magnitude the principal executive bodies and the men holding the principal places come prominently before the world; and as a principle, the men who plan, devise, and really execute are but little known. To such men, however, this country owes no small debt for the indefatigable earnestness with which they have carried their Centennial to a successful issue. To Mr. Henry Pettit, Engineer and Architect of the Main Building and Machinery Hall, and Chief of the Bureau of Installation, more than any other one man connected with the Exhibition, do the people of this country owe a debt of gratitude. He has been the busy bee, the worker *par excellence*, of this vast hive.

As all that relates to the Machinery Bureau is more immediately within the scope and province of this journal, I will—in order that the men who have contributed so efficiently to the success of that branch of the Exhibition may be known to your readers—give the *personnel* of the Bureau. The world pretty well knows now who has been the chief and master mind of this department; and Machinery Hall, as it stood upon the closing day, spoke louder in praise of John S. Albert than any words of mine could. His force of officers and assistants were as follows:

SUPERINTENDENTS.

L. W. ROBINSON, Offices and Installation; JOSEPH HIRST, Machinery Hall; JOHN T. HAWKINS, Buildings south of Machinery Hall; WILLIAM A. DRIPPS, Buildings west of Machinery Hall; L. D. NORTON, Boilers and Steam Pipes.

ENGINEERS.

PHILIP VOORHEES, North-east Section Machinery Hall; WILSON K. PURSE, North-west Section Machinery Hall; G. H. WOODS, South-east Section Machinery Hall; G. B. HUBBARD, South-west Section Machinery Hall; JOHN COTTER, Hydraulic Section, Machinery Hall; PHILLIP PISTER, Buildings south of Machinery Hall; J. D. CURTIS, Buildings west of Machinery Hall; HENRY FAIRFAX, Offices and Installation; J. C. KILGORE, Boilers and Steam Pipes; JAMES HODSON, Shafting, Machinery Hall.

DRAUGHTSMEN.

PERCY A. SANGINETTI, E. F. TOLMAN.

SECRETARY TO CHIEF OF BUREAU.

NAHUM STETSON (3d).

There are few men in this country who are interested in products of the character which made up the grand *tout ensemble* of Machinery Hall, who will not always look back with feelings of pride upon that magnificent assemblage of the fruits of the inventive genius of his countrymen, and they will be glad to learn the names of those who have so ably assisted in its organization, management, and care.

What is true of the Machinery Department in this respect, is abundantly so of all the others; and I might go on and specify only to come to the conclusion which is embodied in these words: The International Exhibition has been a grand success.

J. T. H.

LESSONS IN MECHANICAL DRAWING.

By Prof. C. W. MACCORD.

No. XXXII.

IN Fig. 262 was shown the mode of drawing the cycloid, which is described by a point in the circumference of a circle rolling along a right line. If, on the contrary, we now suppose the straight line to roll on the circle, the curve traced by a marking point in that line will be very different, as shown in Fig. 278. An idea of the nature of the motion of the point in this case may be had in perhaps a clearer way, which the reader may readily illustrate experimentally by fastening a pencil to a string, winding the string upon a cylinder near one end, placing that end flat upon the drawing board, so as to have the cylinder vertical, and then unwinding the string, taking care to keep it always tightly stretched. By this means the string must at all times be straight, and always tangent to the cylinder; and what is more, the part which is unwound must evidently be always equal in length to that part of the circumference upon which it was originally wrapped. If, at starting, we suppose the string to be all wound up on the cylinder, the pencil will be just on the circumference; and as we go on unwinding it, there will be traced a curve which it is easy to see will be of a spiral form, as the pencil goes round the cylinder, but with a constantly increasing radius.

We may, however, describe the curve by points, which are readily found in the following manner: If we suppose the pencil to start at 0 in the figure, and to move in the direction indicated by the arrow, then, when we have unwound so much of the string as is equal to the arc 0 2, that part will be tangent to the circle at 2; and by drawing a tangent at that point, and setting off on it a distance 2 2' equal to the arc, we must by the definition have a point in the curve.

It is most convenient to subdivide the circle into equal parts, which we have done in the diagram, the arc 0 2 being 60°; the operation of rectifying that arc upon the tangent at 2 is indicated, and the line 2-2' thus determined is bisected at *e*.

Then drawing tangents at the points 1, 2, 3, etc., on the circle, we set off 1-1' equal to *e* 2; 2-2' is, of course, twice as great, 3-3' three times, 4-4' four times, and so on; so that 3-3' is one fourth the circumference, 6-6' one half, 9-9' is three fourths, and 0-12' is equal to the whole circumference.

It will thus be seen that the motion of the tracing point is analogous to that by which the spiral of Archimedes was traced, as it travels uniformly along a line, while the latter revolves uniformly; but in this case the line does not pass through the axis about which it turns. Having now gone once round the circle, we may go on, as in the actual case of the string, which may have as many coils as we please: thus extending 1-1', we set off 1'-13 equal to 0-12, since 1-13 must clearly be equal to the whole circumference plus 1-1', and so on.

We have drawn in the figure a ruler tangent to the circle at 8, with a pencil fixed in its edge at 8', which will make clear the fact that this mode of describing the curve is identical with that first mentioned—that is, by the rolling of a right line on a circle; for the points 7, 6, etc., on the ruler, being equally distant from each other, and the spaces thus marked being equal to the arcs of the circle similarly numbered, it will be seen that, as the ruler rolls round the circle, the points 6, 6 will come in contact, also the points 7, 7, and so on, bringing the pencil to the points 6', 7', etc., just as when the string is used.

The distances between the points 5', 6', 7', etc., of the curve, determined by tangents at equidistant points 5, 6, 7, on the circle, increases very rapidly; consequently it will be advisable to ascertain intermediate points, which is very readily done by still farther subdividing the arcs, and adding proportionately to the tangents at the points of subdivision: thus, if we bisect the arc 10-11, the length of the tangent at that point of bisection will be found by adding to 10-10' the half of 1-1' instead of the whole; in this manner we may locate as many points as are desirable.

This curve is called the involute of the circle—or, more commonly, merely the involute—and it is one of much interest and importance, from its applications in the formation of the teeth of wheels. Hence it is advisable for the student to take all the pains possible in its delineation; and, as an aid to its accurate construction, it is to be noted that the method by tangent arcs is applicable in this case also. For it will be observed that at the instant of starting to roll on the *base circle*, from the position shown, the ruler in the figure is really turning on the point 8 as a fulcrum or centre. Consequently, if we describe about 8, with radius 8-8', an arc of a circle, the involute will be tangent to that arc; about 7, describe an arc with radius 7-7', and the curve will be tangent to that also. This being done at all the points of division on the base circle, we may, by making those divisions small, map out our involute with great precision. By this argument it is seen that 7-7' is normal, and the perpendicular to it at 7' is tangent, to the curve; which also, by the same argument, will be tangent to the radius C 0 at the point of beginning. To this last point particularly attention is directed, as it is the part of the curve nearest the base circle which is made use of in the construction of the teeth of wheels, above alluded to. Evidently the involute might be made left-handed as well as right-handed, by unwinding the string in the other direction. If we consider it as traced by the pencil attached to the ruler, it will be seen that, if we move the ruler *against* instead of *with* the clock, the pencil will come eventually to 0, and instantly spring up again from the base circle, tracing, as the motion continues, that left-handed involute, of which a small portion, 0 *b*, is shown on the right of the vertical centre line.

In the case of the cycloid, Fig. 262, the marking point is supposed to be exactly in the circumference of the generating circle. But it need not be so placed; if we imagine a wooden wheel, rolling along the edge of a ruler, and an arm attached to the wheel, but extending beyond its periphery, to carry a pencil, it will be seen that the wheel still controls the motion of the pencil and determines the form of the curve traced by it. This more general case is illustrated in Fig. 279. The wheel and the edge of the ruler are represented by the circle and its tangent L L, the arm by C P, the point P being the pencil. The motion of the circle is the same as in Fig. 262, but P being external to it will trace a different curve. Points in this curve are easily found, since the radius C P is constant; thus, as the circle rolls to the right, the point 2 on its circumference will come into contact with the point E on the tangent, A E being equal to A 2; at that time C will have advanced to D, D E being perpendicular to L L, whence the direction of the generating radius D R is found just as in the case of the cycloid, and its length being given, R is determined. At the end of half a revolution, the centre having advanced to F, the distance C F being equal to half the circumference of the rolling circle, the generating radius will be in the position F S; that is to say, the tracing point S will be as far below the horizontal centre line C F as P is above it. At that instant, G will be the fulcrum upon which the wheel and its arm are turning, and as the circle goes to the right, the point S will move to the left, as shown by the arrow. The result of all this is, that as the pencil is always in advance of—that is, to the right of—the contact radius until the generating radius reaches the position F S, when it lies in the prolongation of that contact radius, the pencil must, as the centre of the circle goes beyond F, rise on the left of F S, thus forming a loop in the curve traced, which is symmetrical about the vertical line S F T, as shown.

The method by tangent arcs applies here too, the point of contact between the base line and the generating circle being at any instant the fulcrum about which the circle, and every point which is rigidly connected with it, like the arm and the pencil in the present instance, may be considered at that instant as turning. Thus, in the original position in the figure, A is the fulcrum, and an arc described about that point with radius A P will be tangent to the curve; in the second position, E is the centre, and E R, equal to 2 P, is the radius of the tangent arc, and so on; the successive points of the tangent being the centres, and the radii being the distances from the corresponding points on the circumference of the rolling circle to the marking point. It will now be readily seen that this is a perfectly general mode of operation, and that the curve traced by any point rigidly connected with any line which rolls on any other line may be mapped out in a similar manner.

It is obvious that the farther the marking point is from the centre the larger will be the loop of this curve, which is called the cartate trochoid, the general name of trochoid being applied to all curves generated by the rolling of one line upon another. In the same figure we have introduced another, the rolling circle being the same, but the marking point being within it, and thus tracing a waved line instead of a looped one. This, which is called the prolate trochoid, the student can now construct without our aid; in selecting the position of the tracing point, he will be guided by the fact that the nearer it is to the centre, the more nearly will the curve approximate to the horizontal right line in which the centre itself travels, while the nearer it is to the circumference, the sharper will be the curvature of the wave at its lowest point. In fact, the nearer the tracing point to the circumference, whether within or without, the greater will be the resemblance of the curve to the limiting form, the common cycloid.

In making illustrative diagrams like the figure, for the purpose of showing how such curves are laid out, we have already stated that there is no objection to drawing the curve itself in a heavy line, although for constructive purposes, as for instance in designing toothed gearing, the lines must be fine. But in the former case the line must be smooth and of uniform thickness, in order to produce an effect at all satisfactory; it will ruin the appearance of the diagram, however accurately it may be drawn, and no matter how excellent the rest of the work may be, if the prominent result of the construction be rough and uneven. And it will be found more difficult to make it smooth and uniform when it is thick than when it is fine: hence it may be worth while to drop a hint as to a means of securing these desirable qualities. As to the smoothness, it is to be observed that it is in any case difficult to make a *very* broad line smoothly at one stroke with the drawing pen. Much of course depends on the skill with which the blades are sharpened or "set," but experience proves that under the best of circumstances a very moderate breadth only can be smoothly executed with certainty. Perhaps one thing may influence this—which is, that if the line be very broad, there is a large quantity of ink lying on the surface, and it may spread out over the limiting edges before it has time to dry. At any rate, the fact exists; and this last point suggests that it would not be desirable to draw a very heavy line at one stroke, even if it were possible, for it would involve not only a great waste of ink, which is not to be overlooked, but worse, a waste of time in waiting for it to dry. In drawing a very broad line, then, it is better to proceed by first drawing two moderately thick ones parallel to each other, being the outer edges, and, when these have dried, filling in the space by drawing a series of others overlapping the first, waiting for each to dry in its turn. When the lines are straight this is very easy, the parallels being drawn with the square or the triangles as the case may be; and circular arcs, of course, present no greater difficulty. But in drawing non-circular curves, there is a very different condition of things, for the outer edge has not the same curvature as the inner one, nor are either of these exactly like the central or original curve from which they are separated by a constant normal distance, and this should evidently be the same on the inside and on the outside. Under these circumstances, the selection and adjustment of the sweeps in such a way as to make just the proper allowance for the differences in curvature, and to secure the perfect regularity and uniformity of the broad line, is something which involves considerable difficulty, and requires much care, some experience, and a well-trained eye. The method of drawing a curve at a constant normal distance from a given one, illustrated in Fig. 156, may be employed here to very good advantage, with the modification more clearly shown in Fig. 280; which exhibits the operation at its various stages, the breadth of the line being greatly exaggerated. A B is the original curve; we now set the bow-pen so as to draw a circle whose diameter is equal to the thickness of the required line, and describe any number of such small circles, with their centres on A B, tangent to which we draw the inner and outer parallels, *cd*, *ef*, and then proceed to fill in the space as above explained. The distances between the centres of the little circles is wholly immaterial; but they must be *circles*, and their centres must be precisely on the curve A B. It is therefore imperatively necessary to have a good spring-bow; which we mention again here more particularly, because it is very easy to find

LESSONS IN MECHANICAL DRAWING.—No. 32.

instruments of that class which look very nice and bright, and may be capable of drawing accurate circles of a moderately large radius, but when screwed down to a very small one will persist in making—closed curves, it is true,—but flattened on one side, or otherwise far from circular. This is generally due to the fact that the spring is too weak, so that the pen, catching on any fibre or irregularity in the surface of the paper, is drawn out of its proper path; sometimes it will be because the point of the pen is too long, so that the other leg has to be inclined, in which case it is almost impossible to manage it so that the inclination shall be uniform as the rotation is performed. But whatever the cause, it may be avoided, and a really good instrument is well worth whatever it may cost in excess of the price of a poor one: the difference in appearance may be very slight, and the selection should in all cases be made by actual trial.

PREPARING THE DRAWING PAPER.

Heretofore we have said nothing about the process of preparing the paper by what is technically called "damp-stretching." It was alluded to, indeed, at an early stage, but not described, for the reasons there given, which were, that it is advisable for a draughtsman to be able to get along without it, that it took up considerable time, and that the accuracy of the work is impaired by the contraction of the paper when it is finally cut loose. This last is the most important objection when working drawings are to be made; but it is, evidently, of no consequence if the drawings are merely illustrative, and as the surface is unquestionably much more smooth and pleasant to work on if the paper be stretched, it may be as well to describe the operation now, for the benefit of those who may not care to pursue the subject in its application to the making of detail plans, or who may at any rate prefer to have the paper as smooth as possible for the work they propose to do.

In order to secure the best results, attention must be paid to a number of minute details; the matter is very frequently treated in a cavalier way by merely stating that the paper is to be wetted, the edges pasted or glued down, and then left to dry. All of which is true, but there is a wrong way as well as a right way to go about most things, and this is one of them.

In the first place, the paper should be prepared by chamfering the edges. This is done by laying it on the board, with the face uppermost on which the drawing is to be made, and with a sharp knife cutting just through the skin—or say half through the thickness of the paper—the knife being guided by a straight-edge laid a quarter of an inch, or a little more, from the edge of the paper. This narrow strip is then to be torn off, care being taken to exert the pressure downward and in such a direction as to pull the strip a little away from the sheet, which may project a little over the edge of the board—as shown in Fig. 281.

The result of this is that the back of the paper will be left not only thin, but rough, for a narrow space along the edge; which serves a double purpose. In the first place, the adhesion will be much more perfect, and what is quite as important, the thinness of the edge greatly facilitates subsequent operations, as the squares and triangles are not so liable to catch upon it.

Next, the edges of the paper are to be folded over, on the face, so as to bring these roughened parts uppermost as the sheet lies on the board. It is not necessary to fold over more than three eighths of an inch all round, if the operator be an expert; a beginner will do well to allow half an inch.

Probably the best adhesive material for this purpose is dextrine, which may be procured at the druggist's; it is a fine powder, which is to be rubbed in a very little water into a thick gelatinous mass, which can be spread on the paper with the finger or a little flat stick; it will not answer at all if made thin enough to flow or to be used with a brush. The advantages of this material are, that it sets quickly, and holds firmly; and more than that, after the paper is cut loose, the adhering edge may be removed by simply sponging it freely and allowing it to soak for a few minutes.

Many use glue; but this requires to be applied rapidly, for it can not be used very thin, and if it dries before the paper is pressed down, there is no remedy but to put on more, while if the like happens with the dextrine, it is only necessary to wet it again like a postage stamp—the gum on which, by the way, is in large part composed of it. Again, it is almost impossible to soak the glue loose again, and it is at best a dirty and disagreeable material to handle in this way. If dextrine be not at hand, the best substitute is a thick paste, made by rubbing wheat flour in cold water until perfectly smooth, after which warm water may be added, and the whole boiled with constant stirring until it becomes a gelatinous mass; if

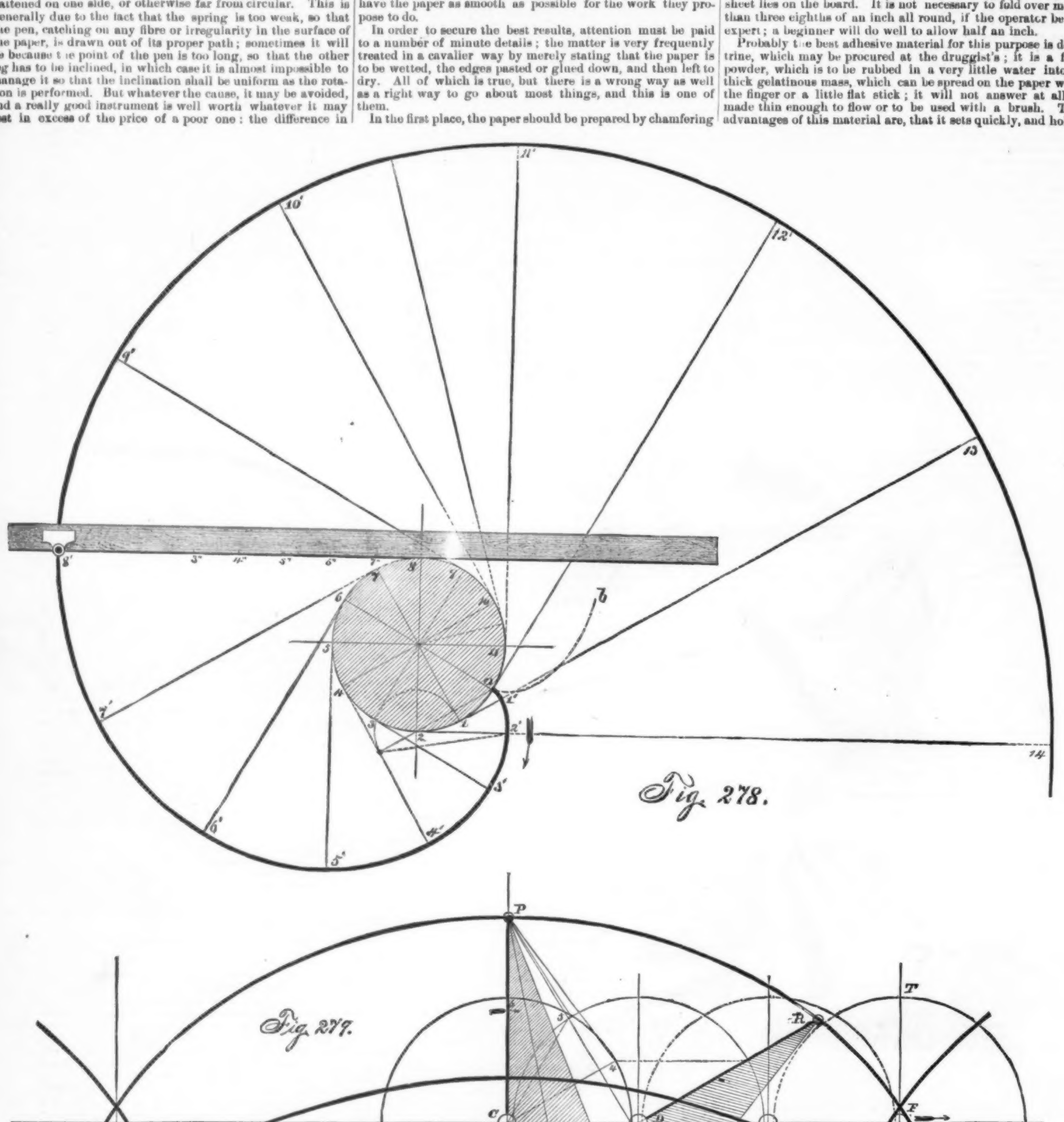


Fig. 278.

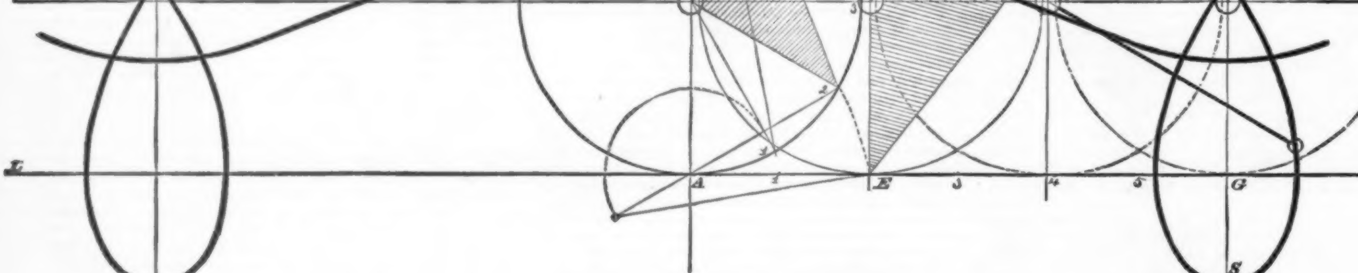


Fig. 277.

desired, the water may have a little glue previously dissolved in it.

Supposing this to be settled, we proceed to turn the paper over, and lay it face downward; the back is then liberally wetted, the sponge being rubbed on it as little and as lightly as possible, since that would tend to remove the sizing. The front or face, of the paper should never be wetted; the sizing is to some extent removed as it is, so that the surface is not quite as smooth as before wetting, at least with the hot-pressed papers; and it would be still worse if the face were sponged. Care should be taken to have the paper wetted as uniformly as possible, which can only be done by careful use of the sponge, as the sheet will tend to curl up at the edges and leave a hollow in the centre. Time must be given for the paper to become thoroughly damp and limp; and this time may be best occupied in cutting a number of strips of waste paper, an inch or so wide.

The sheet is now to be carefully taken up, all the surface water allowed to drain off, and then laid once more in position on its back; it is almost needless to add, that the board should be clean and free from dust: a very small particle of any solid substance, such as a shred of rubber, will be very annoying if allowed to remain under the paper.

The operator should have at hand a sheet of thin paper, say like ordinary foolscap; this is to be laid on the centre of the dampened sheet, and the wrinkles in the latter pressed and rubbed from the middle out toward the sides and ends first, toward the corners last, until it is as smooth as may be; this rubbing should be done with a soft rag like an old handkerchief, but this ought never to touch the surface of the sheet itself, the thin paper being always interposed, as otherwise the surface will be frayed or roughened.

We now begin the operation of pasting down the edges, at the middle of the length, if the paper be longer than it is wide. One of the strips previously cut should be put under the fold, so as to protect the face from being soiled; about two thirds of the longest side may be gummed at first, the edge then turned over, drawn toward the edge of the board as firmly as possible, and then rubbed down. A clean strip of paper should be laid over the edge, however, and the rubbing, with a smooth knife-handle or the like, done over that strip, and not directly on the sheet itself, for if it be, there is danger of tearing it. The middle of the opposite side should next be similarly treated, care being taken to pull it as firmly as possible toward the edge of the board; and it is well to stick a drawing-pin where the gumming or pasting ends.

We now go to one end of the sheet, and repeat the operation, and then to the other: the corners, thus far left to take care of themselves, are finally taken in hand one after the other, and the sheet is then left to dry, after which it will be perfectly smooth and tight.

We have met with instructions to the effect that the proper way is to wet the whole of the *upper* surface, including the edges, and to fasten down the whole of one side or end first, then its next neighbor, and so on round. But we do not hesitate to join issue on these points; especially as to wetting the face on which we propose to draw. As to the edges, there is no necessity for wetting them at all, in the case of a sheet of ordinary size—an "antiquarian" sheet, 31 by 52 inches, may be very successfully stretched without it; and evidently there is risk of impairing the adhesion if the edges be dampened. In stretching exceptionally large sheets, it possibly might be advisable, after wetting the paper on the back, to wet the edges in front, so as to equalize the expansion caused by the moisture; but for all ordinary ranges, the process above explained may be relied on to give most satisfactory results.

The board ought to be perfectly clean, and it will be all the better if the outer parts at least, to which the paste is to be applied, are sand-papered just before using, unless the board has been previously employed in the same way, because the dirt and dust which get imbedded in the grain are apt to prevent adhesion.

The force with which the paper contracts while drying is something quite surprising; and it is well if the board is made slightly convex on its face in the direction of its breadth, —if not absolutely a plane surface, it ought rather to be convex than concave, for in the latter case the paper will not hug the face of the board, but will be slightly separated from it in the central regions; which is very unpleasant, and the points of the compasses are apt to force their way through, when they would not do so were the paper absolutely in contact with and supported by the board.

When the paper is stretched in this way, the work ought to be executed as promptly as possible, because if left too long the paper yields under the strain, and the board contracts, or both, so that wrinkles make their appearance; and when they come, they come to stay, and the result is that all the advantage of smoothness gained by stretching is more than neutralized. If the drawing is to be one from which accurate measurements are to be made, a scale ought to be drawn on the paper; then when the drawing contracts, the scale does too, and the presumption is that it does so in the same proportion, though this is not absolutely certain. When the work is completed, the paper is to be cut off with a sharp knife, care being taken to have the line by which it is cut well within the pasted part; for it is exceedingly aggravating to find a corner or a spot anywhere in the edge stuck fast to the board. As a precaution against this, care should be exercised, while putting the sheet down, to rub *outward*, after the edge has been gummed and turned over; by this means we avoid the spreading of the paste toward the centre. In cutting the paper loose, also, it is to be stated that it is best to cut clear across one side or end, and then attack the adjoining one, and so on in succession. This should be specially observed; we have seen the two opposite ends or sides cut loose first, with the result, that in cutting one of the intermediate ones, the paper would tear across one of the corners as the knife approached the transverse cut. This would only happen, of course, when the paper was very tightly stretched, so as to be still under considerable tension; but it can just as well be avoided as not, by attention to the above simple suggestion.

FIG. 281.—PREPARING THE DRAWING-PAPER.

We may now properly pause for a moment to consider what we have done and what we have still to do. In the series of lessons which has preceded, one object aimed at was to induce some, if possible, to devote spare moments to the acquisition of a fair degree of skill in drawing, who without them might not have done so. In order to do this, we have attempted at first to point out that much may be done by the exercise of patience and by assiduous practice, with comparatively few and inexpensive instruments, in the belief that if a beginning were once made, and a taste for the occupation formed, the interest aroused in the minds of such learners would be permanent and of itself induce them to continue the pursuit, and to procure, as opportunity offered, such additional articles as might be necessary.

Another object was, to give information to such as had already the desire to learn, of such a nature as might enable them to do well what they undertook. In the absence of personal instruction by an expert, the student must rely upon that which can be expressed in writing. And though there are many treatises upon the subject of mechanical drawing, it may be said without hesitation, that the majority, if not all of them, relate more to the theory than to the practice; the minute points in relation to the selection and manipulation of the instruments, upon which much depends, especially at the beginning, are too often, if not always, left for the learner to acquire by experience or the aid of a teacher. To the best of our ability we have endeavored to supply this deficiency; to describe the implements and their uses in such a way as to enable the reader to select and to use them to the best advantage; and in the selection of preliminary exercises we have tried to make them such as to give the learner in the least possible time the most perfect command over the instruments, as well as to train his eye to the detection and his hand to the avoidance or correction of faults.

Keeping in mind that the ultimate application of mechanical drawing is usually to the drawing of machinery, the next step was to the actual representation of solid objects in the manner in which they are drawn for constructive purposes, that is, in projection; after which the construction of such cases of intersecting solids as are always to be met with in mechanism were introduced. The study of projections, as an abstract and preparatory exercise, was an absolute necessity to the making of any satisfactory progress in their application. Possibly, one might acquire skill in drawing machinery by beginning it at once; but it would be a comparatively slow and painful process, since the learner would be continually meeting with cases involving new principles, and would be obliged to stop and master these as he went along. And the same may be said of sections and intersections; though by no means all the cases that would ordinarily arise need be studied as independent exercises, some such study and practice as we have given, is almost as essential a preparatory work as that relating to projections.

Now, we have reached a stage at which the drawing of machinery may be profitably taken up, and we propose to treat of it in succeeding lessons, and to show, as far as our experience enables us to do so, how working drawings and general plans are made. Not, however, to the exclusion of exercises of an abstract nature; for, aside from the fact that such exercises will be found of service in the mere representation of mechanism, in which many new combinations will be met with from time to time, they will have a bearing on branches of the subject not yet touched on—we refer to shades, shadows, and perspective, of which some knowledge is desirable to all, and essential to the finished mechanical draughtsman.

Fig. 280.

And here it may be well, in view of the instructions to follow, to speak more particularly as to the meaning of the word draughtsman. The boundary line between drawing and engineering is a very broad and faint one, so that in this country at least it is not easy to say just when or how or where one ceases to be a draughtsman and becomes an engineer. For our purposes we shall draw this line a little more distinctly; we do not propose to teach engineering, for if we did we might teach heresy, or be accused of it, which is much the same.

Now, the province of the draughtsman, we take it, is to execute what the engineer plans. The proportioning of parts, with reference to strength and durability, is the duty of the engineer; it belongs to him to determine what strains and what wear a given piece is to stand, and how large it must be to do its duty. How he does this it is no part of the draughtsman's duty to inquire; whether he places his dependence on abstruse calculations, or whether he is guided solely by experience and observation, concerns him and no one else. We do not mean to say that a draughtsman is not to ask questions, and learn all he can; but when he asks them he is not drawing, but studying engineering: and if he takes part in making these determinations, he is, in so far as he does so, an engineer. It is his duty to follow the designs of the engineer, just as the mechanic should follow the plans of the draughtsman; the latter is a mean proportional between the other two, and their relations might be expressed in a formula, so dear to the analytic heart, deduced thus:

Engineer : Draughtsman :: Draughtsman : Mechanic,

whence $E \times M = D^2$.

In a word, it is the province of the draughtsman to make drawings of what the engineer decides to be properly proportioned; but he is to make these drawings correctly, and there is much of the nature of planning left for him to do also, since not only is each part to be drawn in detail, but the general arrangement of the whole is to be such that all parts shall fulfil their functions and perform their motions without interference, whence the plotting of mechanical movements is a necessary and important element in his education.

Probably one of the reasons, if not the chief reason indeed, for the unquestionable fact that a chief draughtsman in a machine shop is really an engineer, and that the distinction between the terms is so vague in ordinary use, is that it is almost impossible to acquire the skill necessary to draw machinery with facility, without also acquiring a fund of practical information in regard to engineering: whence it has come to be taken for granted, that he who claims to be a mechanical draughtsman possesses, and must make use of, such information.

But it is not so of necessity; and even if the two kinds of skill and knowledge are in the possession of one individual, they may notwithstanding be separately considered. And we propose to separate them accordingly: giving in illustration of the drawing of details examples taken from approved practice, without undertaking to expound the principles upon which the determination of the dimensions depends, but confining our attention to the matters relating to the execution of the drawings; in regard to which we have things to say which, we hope, may prove both of interest and of value to our readers.

TO UTILIZE BONES.

How to utilize bones without having to carry them a long distance to be ground:—Unless the quantity is very large, the bones should be crushed fine as possible with a heavy iron hammer, mall, or with a large stone mortar. Place the fragments in a heating compost of yard manure and ashes, taking care to moisten it frequently with liquid manure if to be had, or with water in default of the urine. By spreading a thin coat of fresh earth or plaster over the pile, the escape of the valuable ammonia will be prevented. Six months' time will suffice to disintegrate the bones and produce as complete and effective a manure as can be made on the farm. The proportion of ashes to bones should be at least an equal amount of ashes as of bones; more will do no harm. The larger the amount of manure, within reasonable bounds, the better; at least two or three times as much as of both the others is advisable.

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